IOSR Journal of Applied Physics (IOSR-JAP)
e-ISSN: 2278-4861.Volume 11, Issue 6 Ser. II (Nov. – Dec. 2019), PP26-33
www.iosrjournals.org

Determination of Acceleration Due To Gravity in Katagum Local Government Area of Bauchi State

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Abstract: *This research work is meant to investigate the acceleration due to gravity "g" using the simple pendulum method in four difference locations in Katagum Local Government Area of Bauchi State. The locations are; Rafin Tambari, Garin Arab, College of Education Azare and Township Stadium Azare. The results showed that the value of acceleration due to gravity "g" is not constant; it varies from place to place. Best on the results findings, it showed that the Rafin Tambari has the highest value of acceleration due to gravity which is (10.2 m/s^2). In difference location that I used to and Garin Arab has the lowest value of acceleration due to gravity which is (9.73m/s^2). The various results that I have found, reveals that the average value of acceleration due to gravity for Azare area of Katagum Local Government is 9.95m/s^2 which approximately equal to the accepted value of 10.0m/s^2.*

Date of Submission: 18-11-2019 Date of Acceptance: 04-12-2019

I. Introduction

The acceleration due to gravity is the acceleration of a body due to the influence of the pull of gravity. It is usually donated by 'g' Acceleration due to gravity is the constant acceleration of a freely falling body [1].

The determination of the local acceleration due to gravity is one of the oldest experiments performed in physics. Galileo was the first person to find that all objects experience uniform acceleration regardless of their masses. This finding was of great importance since it was used to refute a commonly accepted perception namely that heavier object fall faster than lighter ones. Even today determining the local value of 'g' is important since it can be used to get indirect measurement von the local geological conditions under the surface soil.

This can be done because the greatest contribution to the acceleration of a falling object comes from the matter closest to the object. In particular, the local acceleration depends on the density of this region. Therefore, a measure of the acceleration due to gravity can be given an average density for the crust in the area, and this in turn can be used to determine subterranean composition in a manner. [1]

Thus to determine the acceleration due to gravity experimentally is very important since acceleration due to gravity have diverging values. They are caused by the varying densities of subsurface rocks, location on the surface (such as your latitude) and the elevation (which is the distance from the centre of the earth).

The value of acceleration due to gravity (g) can be determined using different methods namely simple pendulum, free fall, reversible pendulum etc.

Moreover, the acceleration due to gravity has an effect on many physical quantities. This includes kinematics (motion under free fall and projectile motion), newton's law of gravitation (density of the earth and weight of a body), atmospheric pressure, escape velocity and potential energy of system etc. however the acceleration due to gravity is not constant everywhere on the surface of the earth, i.e. it varies from place to place due to the following reason; the rotation, shape and the density of the earth, the variation in latitudes and altitudes.

II. Aim and Objectives

The aim of this project is to investigate and determine the acceleration due to gravity (g) in some areas in Katagum Local Government of BauchiState. The objectives include:

I. To measure the acceleration due to gravity 'g' in some areas in Katagum Local Government of Bauchi State.
II. To used suitable statistical method of descriptive statistics to determine the acceleration due to gravity 'g' in some areas in Katagum Local Government of Bauchi State.

Relevance of the Study

Many scientists predict that the value of acceleration due to gravity lies between 9.8 and 10.0 m/s^2, but it varies from place to place due to some geological factors, [1]. Hence the need to know the value for "g" in our locality.

Scope and Limitation

The scope of this work cover the experimental and statistical investigation and determination of acceleration due to gravity 'g' this work is limited to simple pendulum method out of the five different methods of determination of acceleration due to gravity 'g' in some areas in Katagum Local Government of Bauchi State.

Historical Development

A simple pendulum can be described as a point mass suspended by a mass less string from some point about which it is allowed to swing back and forth in a place [2].

A story is told of Galileo that he was once attending a service in the cathedral at Pisa. When his attention was distracted by the swinging of a lamp which was suspended from the roof by a long chain. Using the beats of his pulse as a clock, he noticed that the time of swinging of the lamp is remained constant even when the oscillations were dying away. The lamp was behaving as a pendulum. Thus it was Galileo who first observe that the time a pendulum takes to swing back and forth through small distances depends only on the length of the pendulum. The swings back and forth constitute the pendulum motion and it will be periodic. So the time that it takes to make one complete oscillation i.e. swings back and forth is defined as the period [1] reported that the time of this to and fro motion, called, called the period, does not depend on the mass of the pendulum or on the size of the are through which it swings.

Another factor involved in the period of motion is, the acceleration due to gravity "g" which on the earth is $9.8m/s^2$. It is the acceleration for all free-falling objects, regardless of their mass or weight [3].
whereas due to atmospheric pressure, g decreases abruptly. This in accordance to [3].

Variation of Acceleration Due Gravity from Place to Place

The value of 'g' goes on changing from place to place on the earth's surface. It is maximum at the poles and decreases toward the equator [4]. There are two reasons for this VIZ. (i) shape of the earth and (ii) rotation of the earth.

(i) Due to shape of the Earth: Earth is not a perfect sphere; it is more nearly a spheroid having its polar radius smaller than the equatorial radius [5]. So from Newton's law of gravitation, a body at the pole would attract more strongly than the body at the pole, so the value of g is more at pole and least at the equator.

(ii) Due to the rotation of the Earth the rotation of the earth reduces the force you feel at your feet, (you would therefore feel lighter at the equator than at the poles of the shaped like an oblate spheroid, meansthat the radial distance you are from the centre of the earth (and gravity) varies depending on where you are on the surface. Both of these effects vary with latitude, and this variation is predictable, and is given by an equation known as the international gravity formula, as equation known as the international gravity formula, as established by the wold geodetic system 1984 [6].

Various Methods of Determination of Acceleration due to Gravity'g'

There are different methods of determination of acceleration due to gravity such as simple pendulum, reversible pendulum, free fall method etc.
The weight of an object is the total gravitational force exerted on the object by all other objects in the universe. The weight of an object varies from place to place due to the variation in the acceleration due to gravity [7].

Effect of Acceleration due to Gravity

The acceleration due to gravity has effects on many physical quantities in physics. But in this context, only kinematics (i.e. free fall and projectile motion), Newton's law of gravitations (density of the earth and weights of the body), atmosphere pressure, escape velocity and minerals exploration etc.

Theory

The time that a pendulum takes to make one complete oscillation is defined as the period T. the frequency "f" of the oscillation is the number of oscillations that occur per unit time and is the inverse of the period f=$\frac{1}{7}$.
Consider the equation of motion from free body diagram in figure 1
Resolving the weight-gravitational force into two components-one along the radial direction, and one along the arc in the direction that the mass moves.

The restoring force, f=ma = mgsinθ (1)

The minus sign indicates that the force in opposite to the displacement.

For small amplitude where θ is small, sin θ = θ in radia

F= -mg θ (2)

But θ= $\frac{arc}{radius}$ radian = $\frac{\times}{l}$ so that

$$F = -mg\frac{x}{l} \quad (3)$$

When a simple pendulum is displaced from its equilibrium position, there will be a restoring force that moves the pendulum back towards its equilibrium position. This restoring force F is opposite and directly proportional to the displacement x from the equilibrium position so that

$$F = -kx \quad (4)$$

And then the motion of the simple pendulum is SHM and its period can be calculated using the equation for the period of SHM,

$$T = 2\pi\sqrt{\frac{m}{k}} \quad (5)$$

Comparing equation (3) and (4), $k = \frac{mg}{l}$ (6)

Substituting the value of k in (1) into equation (5) gives

$$T = 2\pi\sqrt{\frac{m}{mg/l}} = 2\pi\sqrt{\frac{l}{g}} \quad (7a)$$

Therefore, for small amplitudes the period of a simple pendulum depends only on its length and the value of the acceleration due to gravity.

Equation of Period of a Pendulum

The period of a pendulum is given by the equation

$$T = 2\pi\sqrt{\frac{l}{g}} \quad (7b)$$

Where T is time period, L effective length of pendulum,

Then

$$g = 4\pi^2 \cdot \frac{L}{T^2} \quad (8)$$

Plotting a graph of T^2 against L will give slope

$$Slope = \frac{T^2}{L} \quad (9)$$

Therefore

$$g = 4\pi^2 \cdot \frac{1}{slope} \quad (10)$$

Newton's Law of Gravitation

The example of gravitational attraction that is most familiar to you is your weight, the force that attracts one towards the earth. During his study of the motions of the planets and the moon. Newton published the law of gravitation in 1687; stated as follows.

Every particle of matter in the universe attracts every other particle with force that is directly proportional to the product of the masses of the particle and inversely proportional to the square of the distance between them.

$$Fg = G\frac{m_{1}m_{2}}{r^2} \quad (11)$$

When F_g is the magnitude of the gravitational force on either particle; m_1 and m_2 are there masses, r is the distance between them, G is the fundamental physical constant called the gravitational constant.

The symbols g and G are almost the same, its common to confuse the two gravitational quantities that these symbols represent. Lower case g is the acceleration due to gravity which relates the weight of a body to its mass m, w=mg. The value of g is different at different location on the earth's surface and on the surface of different planets.

Materials/Apparatus

The materials and tools used in the project work include; retort stand and clamp, pendulum bulb, cotton thread, metre rule, stop watch, load or known mass, hanger, and steel ball.

Location of Research

The project took place in some areas in Katagum Local Government of Bauchi State. The locations of the work are; Rafin Tambari, Garin Arab, College of Education and Township Stadium Azare.

Method of Determination of Acceleration due to Gravity 'g'

Although there are many ways of determining the acceleration due to gravity 'g' of certain location but the method used in this work is simple pendulum method.

The simple pendulum is shown in figure 1. It consist of a small bob (in theory a particle) of mass m suspended by a light inextensible thread of length 1 from some point about which it is allowed to swing back and forth.

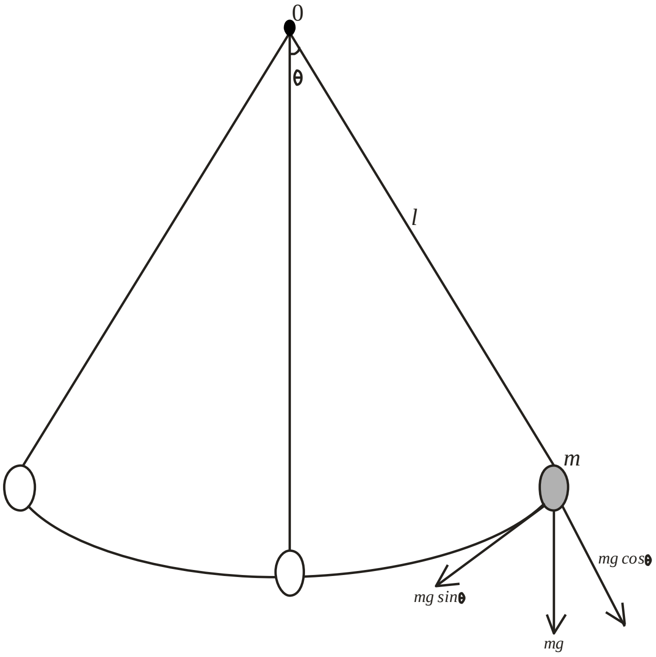

Figure 1: Simple Pendulum [8]

The force on the bob are the tension in the thread, T, and the weight, mg, of the bob acting vertically downwards (as shown in figure 2). Resolving mg vertically and tangentially at appoint A it was observed that the tangential component is the unbalanced restoring force acting towards the equilibrium position 0.

The acceleration due to gravity at a place can be calculated by knowing the approximate values of time period of oscillation and length of pendulum.

Calculation

Equation (7), $T^2 = \frac{4\pi^2}{g}1$, is of the form y = ax+b where y = T^2, a = $\frac{4\pi^2}{g}$, X=1, and b = 0.

A graph of T^2 versus 1 should therefore result in a straight line whose slope, a, is equal to $\frac{4\pi^2}{g}$. From the equation for the trend line, record the value for the slope, a, and from the equation a= $\frac{4\pi^2}{g}$ g is the acceleration due to gravity.

Precaution

The following are the major precaution taken to ensure accurate result;

i. Avoid error due to parallax.
ii. Observations were repeated always before taken reading.
iii. The angle of suspension must be very small $\leq 30^0$.
iv. Avoid damping effect of pendulum bob.

III. Results

The measurement for the determination of the values of acceleration due to gravity in some areas in Katagum Local Government was conducted.

The results are as follows:

Table 1 Acceleration due to gravity at Township stadium Azare using simple pendulum.

S/N	L(m)	T/(s)	$T^2/(s^2)$
1	0.20	0.91	0.83
2	0.30	1.10	1.21
3	0.40	1.27	1.6
4	0.50	1.42	2.6
5	0.60	1.56	2.4
6	0.70	1.68	2.8

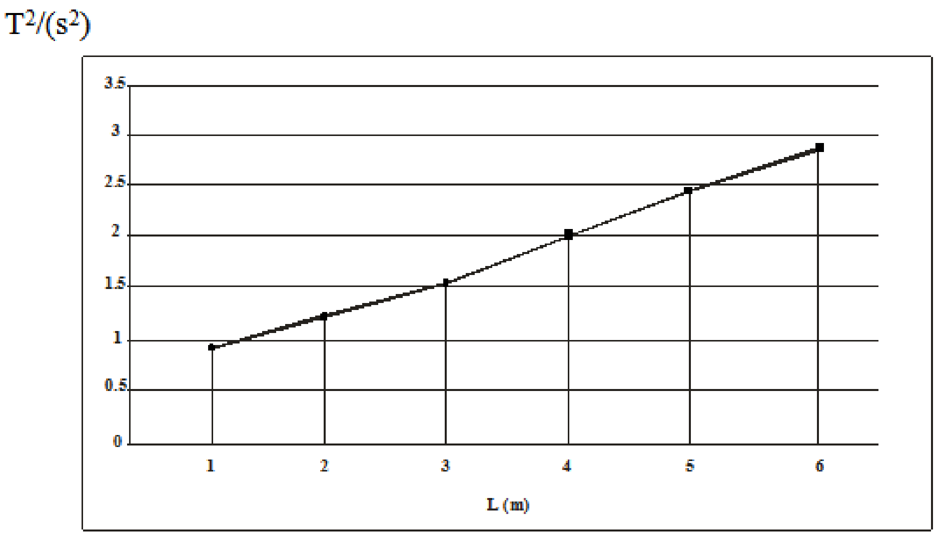

Figure 2: A graph of T^2 against L for Township Stadium Azare

Slope $= \frac{DT}{DL}$

Slope $= \frac{T^2 2 - T^2 1}{L_2 - L_1}$

Slope $= \frac{2.8 - 1.5}{0.7 - 0.37}$

Slope $= \frac{1.3}{0.33}$

Slope $= \underline{\underline{3.9}}$

To determine "g" we use this formula slope s $= \frac{4\pi^2}{g}$

Then g $= \frac{4\pi^2}{s}$

g $= \frac{4 \times 9.88}{3.9} = \frac{39.489}{3.9}$

g $= \underline{\underline{10.1 m/s^2}}$

Table 2 Acceleration due to gravity at College of Education, Azare

L(m)	T/(s)	$T^2/(s^2)$
0.20	0.91	0.82
0.30	1.10	1.21
0.40	1.26	1.59
0.50	1.41	1.99
0.60	1.55	2.40
0.70	1.68	2.82
Average = 0.45		

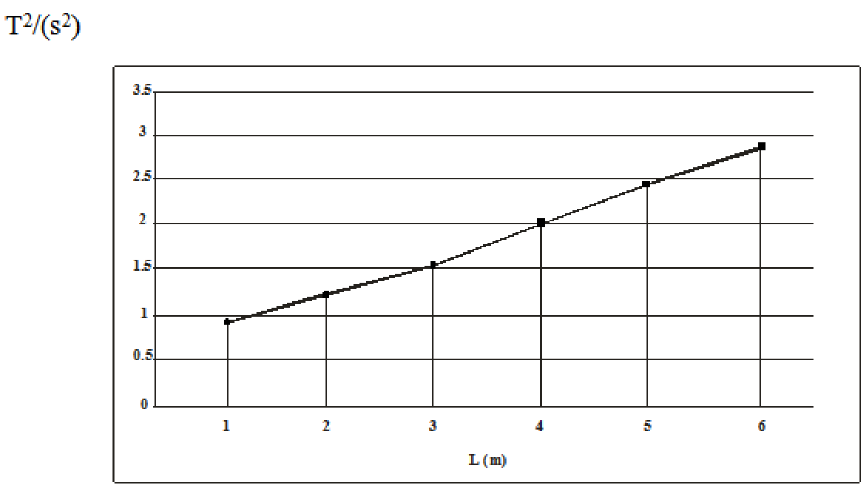

Figure 3: A graph of T^2 against L for College of Education, Azare

From the graph, Slope = $\frac{T^2 2 - T^2 1}{L_2 - L_1}$

∴ Slope = $\frac{2.8-1.75}{0.7-0.44}$

Slope = $\frac{1.05}{0.26}$

Slope = 4.04

To determine "g" at College of Education, Azare we use this formula s = $\frac{4\pi^2}{g}$

Then g = $\frac{4\pi^2}{s}$ = $\frac{4 x 9.878}{4.04}$

∴ g = $\frac{39.510}{4.04}$

g = 9.779

g = $9.78 m/s^2$

Table 3 Acceleration due to gravity at Garin Arab

S/N	L(m)	T/(s)	$T^2/(s^2)$
1	0.20	0.90	0.82
2	0.30	1.11	1.22
3	0.40	1.27	1.62
4	0.50	1.42	2.02
5	0.60	1.56	2.44
6	0.70	1.68	2.83

$T^2/(s^2)$

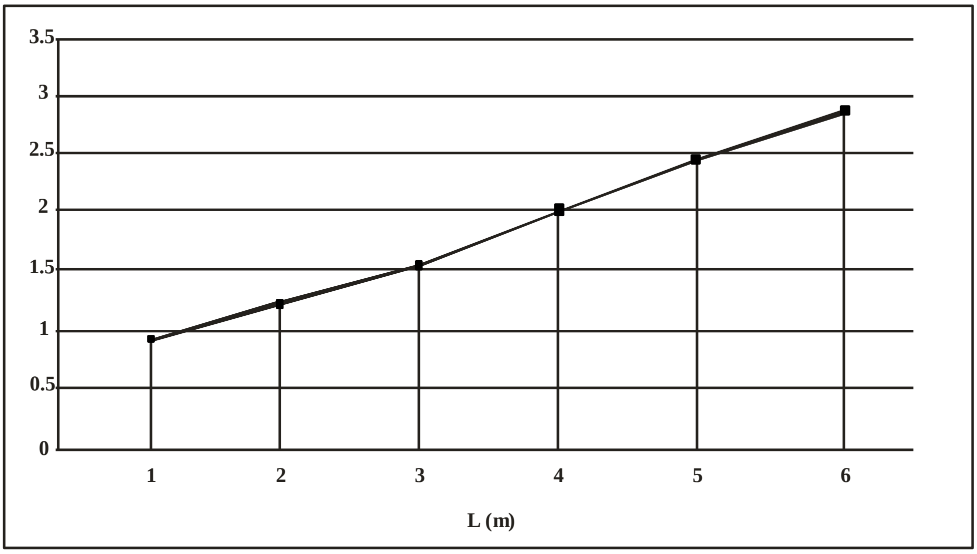

Figure 4: A graph of T^2 against L for Garin Arab

From the graph, slope of the graph shows this

Slope = $\frac{T^2}{L}$

Slope = $\frac{2.8-1.75}{0.7-0.44}$

Slope = $\frac{1.05}{0.26}$

Slope = 4.06

To determine "g" at Garin Arab Azare we are to use this formula slope s = $\frac{4\pi^2}{g}$

Then g = $\frac{4\pi^2}{s}$

g = $\frac{4 x 9.878}{4.06}$

g = $\frac{39.510}{4.06}$

g = $9.73 m/s^2$

Table 4 Acceleration due to gravity at Rafin Tambari

The following data are obtained:

S/N	L(m)	T/(s)	$T^2/(s^2)$
1	0.20	0.94	0.9
2	0.30	1.14	1.3
3	0.40	1.34	1.8
4	0.50	1.48	2.2
5	0.60	1.61	2.6
6	0.70	1.70	2.9

$T^2/(s^2)$

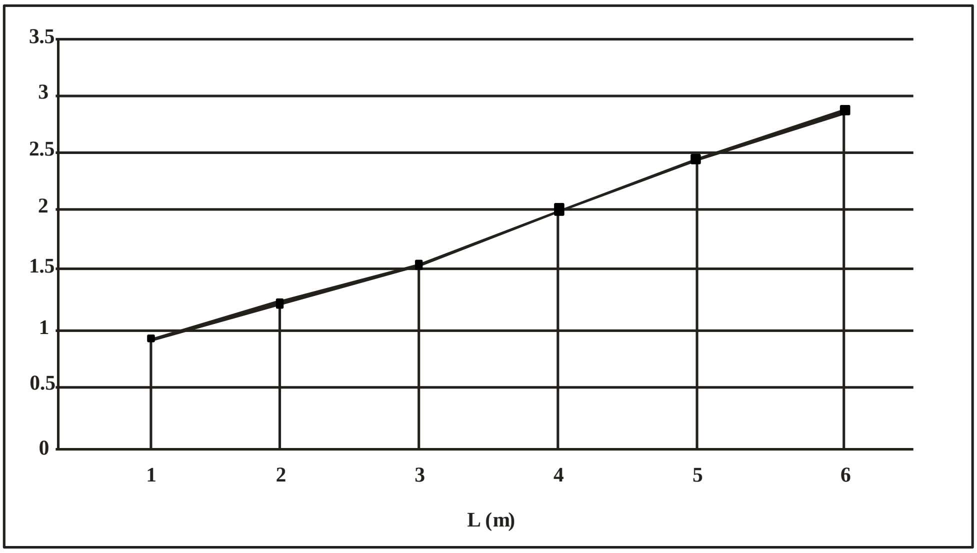

Figure 5: A graph of T^2 against L for Rafin Tambari

Slope = $\frac{T^2 2 - T^2 1}{L_2 - L_1}$

Slope = $\frac{2.9 - 1.5}{0.7 - 0.34}$

Slope = $\frac{1.4}{0.36}$

Slope = $\underline{\underline{3.89}}$

To determine "g" at Rafin Tambari, we use this formula to compute the "g" from s = $\frac{4\pi^2}{g}$

Then g = $\frac{4\pi^2}{s}$

g = $\frac{4 \; x \; 9.878}{3.89}$

g = $\frac{39.510}{3.89}$

g = 10.1568

g = $\underline{\underline{10.2 m/s^2}}$

IV. Discussion

Different Values of "g" in Four Locations

S/N	Names of Location	g (m/s^2)
1	Township stadium, Azare	10.1 m/s^2
2	College of Education, Azare	9.78 m/s^2
3	Rafin Tambari	10.2 m/s^2
4	Garin Arab	9.73 m/s^2
	Average	**9.95 m/s^2**

From the table above shows the difference of acceleration due to gravity obtained in difference location in Katagum Local Government, we have the highest value of £g£ at Rafin Tambari which is 10.2 m/s^2. This is due to the altitude and latitude of the area. Also Rafin Tambari is more denser area, so the more denser the area the more value of "g" will be obtained. The Rafin Tambari is among the denser place in Katagum Local

Government. Township stadium is having 10.1m/s^2, also is among the denser area in Katagum Local Government. College of Education Azare (9.78m/s^2) and Garin Arab (9.73m/s^2) has the lowest value of "g" this because they are place of less denser, since the more denser the place is, the more value of "g" will be obtained, likewise the less denser the place is, the small value of "g" will be obtained.

The average values of the experiment shows that the "g" is 9.95 m/s^2. Which is nearest to the accepted value of "g" which is 10.0m/s^2.

% Difference $\frac{(\textbf{\textit{Experiment Result}}-\textbf{\textit{Theoretical Result}})}{\textbf{\textit{Theoretical Result}}}$ **x 100%**

$= \frac{9.95-10.0}{10.0} \times 100$

$= \frac{-0.05}{10} \times 100$

$= -0.005 \times 100$

$= \underline{\underline{-0.5\%}}$

This shows that we have only (- 0.5%) of errors in the experiment which is a less error or only small error we have fund in the experiment.

Statistical Analysis

From the equation of mean i.e

Mean x = $\Sigma\ \frac{x_1+x_2+x_3}{\Sigma nx}$

Then substitute the values of x_1 --------- x_n

Therefore x = $\frac{10.1 + 9.78 + 10.2 + 9.73}{4}$

Medium distribution = 9.95

V. Conclusion

In conclusion, the acceleration due to gravity has been experimentally investigated using simple pendulum at Garin Arab, Rafin Tambari, College of Education and Township Stadium, Azare. The result reveals that the average value of acceleration due to gravity for Katagum Local Government Area was found to be 9.95m/s^2 which are nearest to the accepted value of 10.0m/s^2[1].

Despite the limitation of this work, the result obtained is adjusted accurate due to the result of the investigation. Thus the value obtained could be use by any scientist in any field that requires a constant value of acceleration due to gravity (g).

Due to the fact that acceleration due to gravity could be obtained using several methods and only one is used, I recommend the use of other methods for further investigation; gravity magnitude is often used in engineering calculations and many other applications such as geophysical exploration and so on. There is a need of the development of new geophysical applications.

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D. Dahuwa. "Determination of Acceleration Due To Gravity in Katagum Local Government Area of Bauchi State." IOSR Journal of Applied Physics (IOSR-JAP) , vol. 11, no. 6, 2019, pp 26-33.